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Do Nuclear Star Clusters and Supermassive Black Holes Follow the Same Host-Galaxy Correlations?⋆

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ABSTRACT

Studies have suggested that there is a strong correlation between the masses of nuclear star clusters (NSCs) and their host galaxies, a correlation which said to be an extension of the well-known correlations between supermassive black holes (SMBHs) and their host galaxies. But careful analysis of disk galaxies – including 2D bulge/disk/bar decompositions – shows that while SMBHs correlate with the stellar mass of the *bulge* component of galaxies, the masses of NSCs correlate much better with the *total* galaxy stellar mass. In addition, the mass ratio $M_{\rm NSC}/M_{\star,\rm tot}$ for NSCs in spirals (at least those with Hubble types Sc and later) is typically an order of magnitude smaller than the mass ratio $M_{\rm BH}/M_{\star,\rm bul}$ of SMBHs. The absence of a universal "central massive object" correlation argues against common formation and growth mechanisms for both SMBHs and NSCs. We also discuss evidence for a break in the NSC–host galaxy correlation: galaxies with Hubble types earlier than Sbc appear to host systematically more massive NSCs than do types Sc and later.

Key words. galaxies: structure – galaxies: elliptical and lenticular, cD – galaxies: spiral – galaxies: kinematics and dynamics

1. Introduction

As far as we can tell, all massive galaxies in the local universe harbor supermassive black holes (SMBHs, with masses $M_{\rm BH} \sim 10^6$–$10^9 M_\odot$). The masses of these SMBHs correlate strongly with several global properties of the host galaxies, particularly with the central velocity dispersion σ_0 [1, 2] and with the bulge luminosity or mass [e.g., 3, 4]. These correlations imply that the processes which drive galaxy growth and the processes which drive black hole growth are intimately linked – perhaps even the *same* processes.

It is now also clear that many galaxies, particularly later-type spirals, host luminous nuclear star clusters [NSCs; e.g., 5, 6], with masses in the range 10^5–$10^8 M_\odot$; see the review by Böker [7] for more details. Recently, several authors have argued that NSCs and central SMBHs have the *same* host-galaxy correlations: in particular, that SMBHs and NSCs have the same correlation with bulge luminosity and mass [8, 9, 10, 11] (but see Balcells et al. [12]). The suggestion, then, is that NSCs and SMBHs are in a sense members of the same family of "Central Massive Objects" (CMOs), and thus that they may have grown via the same mechanisms [e.g., 13, 14, 15, 16].

We argue, however, that one should be cautious about assuming that NSCs and SMBHs are really part of the same family, with the same host-galaxy relationships. To begin with, the samples of Wehner and Harris [8] and Ferrarese et al. [9], which were used to make the CMO argument, were almost entirely early-type galaxies – mostly ellipticals and dwarf ellipticals. These are galaxies which are, in essence, "pure bulge" systems, so one could just as easily argue for a correlation with *total* galaxy mass. But we know that SMBHs in *disk* galaxies correlate better with just the bulge, and *not* with the total galaxy mass or light [e.g., 17, 18]. Given that there have been previous claims that NSCs in spiral galaxies correlate with the *total* galaxy light [e.g., 19], we are prompted the ask the question: do nuclear clusters *in disk galaxies* correlate with the bulge (like SMBHs), or with the whole galaxy?

2. Samples, Methodology, and Data Sources

Although current studies suggest that the $M_{\rm BH}$-σ_0 relation is tighter and has less intrinsic scatter than the $M_{\rm BH}$-$M_{\star,\rm bul}$ relation [e.g., 20], velocity dispersion is *not* the ideal host-galaxy measure to use here, for three reasons. First, most of the best-determined NSC masses are based directly on the measured velocity dispersion of the NSC [e.g., 21], which is often indistinguishable from that of the surrounding bulge; this means a (spurious) correlation between NSC mass and central velocity dispersion is only to be expected. Second, some NSCs are found in galaxies with *no* detectable bulge at all (see discussion in Section 3). Finally, it is difficult to see how one should discriminate between a velocity dispersion due to the bulge versus one due to the whole galaxy. But discriminating between bulge and whole-galaxy luminosities and masses is much simpler. So we choose instead to compare NSCs and their host galaxies with the $M_{\rm BH}$-$M_{\star,\rm bul}$ relation, which means comparing NSC masses with the *stellar masses* of host galaxies and their bulges.

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For NSCs, we emphasize galaxies where the NSC masses have been *dynamically* measured, since this is the most direct analog to well-determined SMBH masses (i.e., those with direct dynamical mass measurements from stellar, gas, or maser kinematics, where the SMBH sphere of influence is resolved). In addition, dynamical measurements avoid possible problems with multiple stellar populations; the latter can potentially bias stellar masses estimated from broad band colors. Spectroscopic studies [22, 11] have shown that NSCs often contain multiple stellar populations; this renders mass estimates based on Single Stellar Population (SSP) models [e.g., those used by 9] somewhat uncertain. The NSCs we focus on are taken primarily from the sample of Walcher et al. [21], with additional data from Ho and Filippenko [23], Böker et al. [24], Kormendy and Bender [25], Matthews et al. [26] and Gebhardt et al. [27], Barth et al. [28], Seth et al. [29], and Kormendy et al. [30]; we use the estimate of Launhardt et al. [31] for the Milky Way's NSC. This gives us a total of 18 galaxies with dynamically determined NSC masses. These cover Hubble types S0–Sm, but the sample is in fact heavily biased towards later types: over three-quarters are Hubble types Scd or later. As an additional, secondary sample, we include 15 galaxies from Rossa et al. [11], where the masses are estimated by fits of multiple SSP models to high-resolution spectroscopy. Most of these galaxies are Sc and later, but a few earlier-type spirals (Sa–Sb) are also included.

Total stellar masses are based on K-band total magnitudes from 2MASS [32] or from Malhotra et al. [33] for M31 and M33 (which are too large for accurate sky subtraction of 2MASS images), combined with color-based mass-to-light (M/L) ratios from Bell et al. [34]. For the latter we use optical colors from the literature (primarily from HyperLeda[1]) or from direct measurements on Sloan Digital Sky Survey [SDSS, 35] images. The *bulge* masses are derived using bulge-to-total (B/T) values determined individually for each galaxy by 2D image decomposition, using the BUDDA software package [36, 37], which incorporates bulge and disk components *and* optional bars and central point sources (the latter can be used for both nuclear star clusters and AGN). Note that we explicitly define "bulge" to be the "photometric bulge" – that is, the excess light (and stellar mass) which is not part of the disk, bar, or nuclear star cluster. We defer questions of how SMBH (or nuclear cluster) mass relates to so-called "pseudobulges" versus "classical bulges" [e.g., 38, 39] to a later analysis.

Full 2D decompositions, as described above, were used for all S0 and spiral SMBH host galaxies. For the NSC host galaxies, we follow the same approach, with one simplification. Since we have found that B/T ratios for *unbarred* galaxies do not change dramatically if we use 1-D surface-brightness profile decompositions instead of 2D image decompositions, we use the former for genuinely unbarred galaxies; we are careful to exclude (or separately model) the NSC contribution to the surface-brightness profile in these cases. Galaxies which *do* possess bars are subjected to full 2D decompositions; see the following section for details.

2.1. Bulge-Disk Decompositions

As noted previously, we use 2D image decompositions via the BUDDA software package to determine the B/T ratios, and thus the bulge stellar masses, for SMBH host galaxies and for barred NSC host galaxies. For the NSC galaxies, we use *HST* data wherever possible, to enable the NSC itself to be properly modeled as a separate source. However, we have found that when the NSC is sufficiently luminous, and when the bulge is sufficiently low-contrast, we can achieve reasonable decompositions with ground-based images; these are sometimes preferable if they are near-IR (to minimize the effects of dust extinction and recent star formation) and/or large enough to include the entire galaxy (to allow better recovery of the disk component).

We have completed decompositions for the galaxies with dynamically determined NSC masses (we use the published 2D decomposition of [28] for NGC 3621); in the special case of the Milky Way, we assume a bulge mass of $\sim 1.0 \times 10^{10} M_{\odot}$ and a total stellar mass of $5.5 \times 10^{10} M_{\odot}$, based on arguments in Dehnen and Binney [40], Klypin et al. [41], and Flynn et al. [42]. Decompositions for the spectroscopic sample are still in progress, but are mostly complete; since our primary analysis (e.g., computing the $M_{\rm NSC}$-$M_{\star,\rm bul}$ relation) is based on the dynamical masses, the incompleteness of the spectroscopic sample does not affect our results.

Full details of the individual decompositions will be published elsewhere (Erwin & Gadotti 2012a, in prep.). An example of one of the 2D decompositions is given in Figure 1 for the galaxy NGC 7418, where we fit an H-band image from the Ohio State University Bright Spiral Galaxy Survey [43, OSU BSGS] using an exponential disk (95.6% of the light), a Sérsic bulge (1.6% of the light), a bar (2.4% of the light), and a point source for the NSC (0.5% of the light).[2] This illustrates the importance of including a separate bar component in the decomposition when the galaxy is barred: the bar has almost twice the luminosity of the bulge, and without it, the bulge luminosity (and stellar mass) would certainly be overestimated. In fact, a 1-D decomposition for this galaxy gives a B/T value almost twice as large (0.030); similar results were found for four other barred galaxies in the sample, with mean B/T values a factor of 2.1 times larger when the bar was omitted [see also 37].

3. Comparing Black Holes and Nuclear Star Clusters

Although black-hole–bulge correlations are sometimes described as correlations between the black hole mass and the host *galaxy* mass (or luminosity as a proxy for mass), this is really only true for elliptical galaxies, where the entire galaxy is the "bulge". Kormendy and Gebhardt [17] explicitly compared B-band total and bulge luminosities for SMBH hosts and showed that the latter provided a much better correlation. Most recently, Kormendy et al. [18] showed for a larger, updated sample that SMBH masses in disk galaxies correlated much better with (classical) bulge K-band luminosity than with the luminosity of the disk component; this naturally suggests that total-galaxy luminosity is unlikely to correlate well with SMBH mass when the galaxy is disk-dominated.

In Figure 2, we compare SMBH masses with total galaxy stellar mass (left panel) and with bulge stellar mass (right panel), based on our careful bulge/disk/bar decompositions (see Table A.1). Error bars include the effects of uncertainties in the distance and in the

[1] http://leda.univ-lyon1.fr

[2] In this particular galaxy, the disk appears to be truncated, but this has little effect on the decomposition; including a broken-exponential profile for the disk changes the B/T ratio from 0.016 to 0.017.

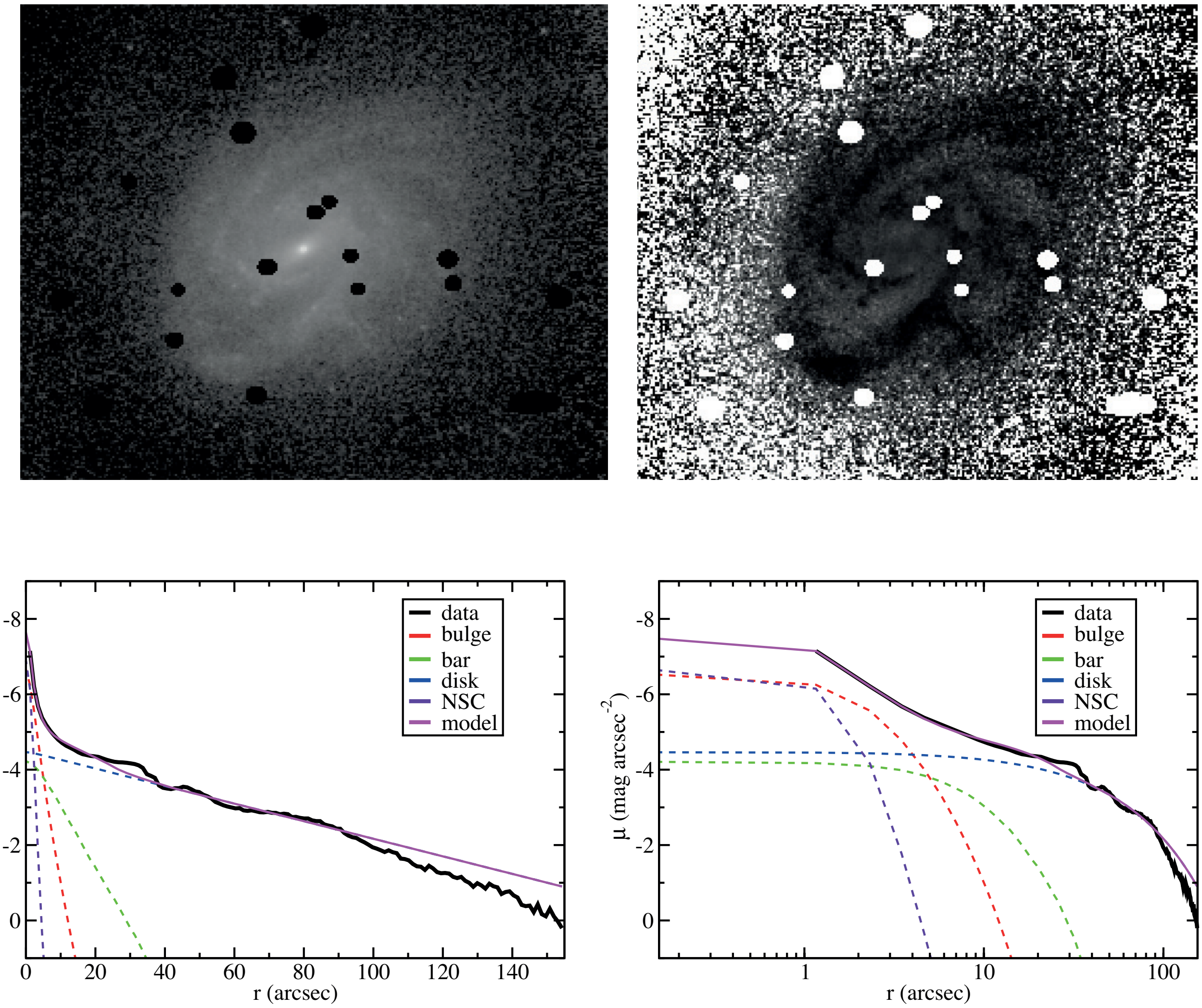

Fig. 1. An example of one of our 2D decompositions of NSC host galaxies – in this instance, the decomposition of the OSU BSGS H-band image of NGC 7418, using an exponential disk, a Sérsic bulge ($n = 1.5$), a bar, and a point source for the NSC. **Upper left:** Original H-band image, with masking of bright stars (logarithmic brightness scaling). **Upper right:** Residual image after subtracting best-fitting model image. **Lower left:** Major-axis profile (black) along with the components of the model and their sum (purple). **Lower right:** Same, but plotted with logarithmic major-axis scaling.

M/L and B/T ratios. As expected, the correlation between SMBH mass and *bulge* mass is much stronger than any correlation with total galaxy mass: the Spearman correlation coefficients are $r_S = 0.71$ for the $M_{\rm BH}$-$M_{\star,\rm bul}$ relation, versus 0.29 for the $M_{\rm BH}$-$M_{\star,\rm tot}$ relation, with the latter correlation not being statistically significant.

We also plot linear fits of $\log M_{\rm BH}$ as a function of $\log M_{\star,\rm bul}$; these fits are made using galaxies with well-determined distances (filled points) to minimize distance-based uncertainties, using the Bayesian-based approach of D'Agostini [44], which explicitly incorporates errors in both variables and intrinsic scatter in the black hole mass [see also 45, 46]. By "well-determined distances" we mean those determined using direct methods such as surface-brightness fluctuations and Cepheid stars, or redshift-based distances where $z > 0.01$ (to avoid large relative uncertainties due to peculiar motions.) The best-fitting relation for the whole sample (black line; the fit to just the elliptical galaxies, shown by the red line, is almost identical) is:

$$\log M_{\rm BH} \;=\; 8.46 \pm 0.08 \;+\; (1.04 \pm 0.12)\,\log(M_{\star,\rm bul}/10^{11} M_{\odot}), \tag{1}$$

with intrinsic scatter in SMBH mass of 0.39 ± 0.05 dex; the best-fitting relation for the bulges of disk galaxies only (blue line) is

$$\log M_{\rm BH} \;=\; 8.68 \pm 0.20 \;+\; (1.27 \pm 0.26)\,\log(M_{\star,\rm bul}/10^{11} M_{\odot}), \tag{2}$$

with instrinsic scatter $= 0.41 \pm 0.07$. (The errors are based on bootstrap resampling.)

We apply exactly the same methodology to NSC-host galaxies in Figure 3, plotting NSC mass versus total galaxy stellar mass in the left panel and versus bulge stellar mass in the right panel. Since several of the NSC host galaxies are genuinely *bulgeless* systems (without even a distinct "pseudobulge"), we plot their bulge masses as upper limits ($B/T < 0.001 M_{\star,\rm tot}$). As the figure shows, NSC mass clearly correlates better with *total* stellar mass than it does with bulge mass. (The respective correlation coefficients are

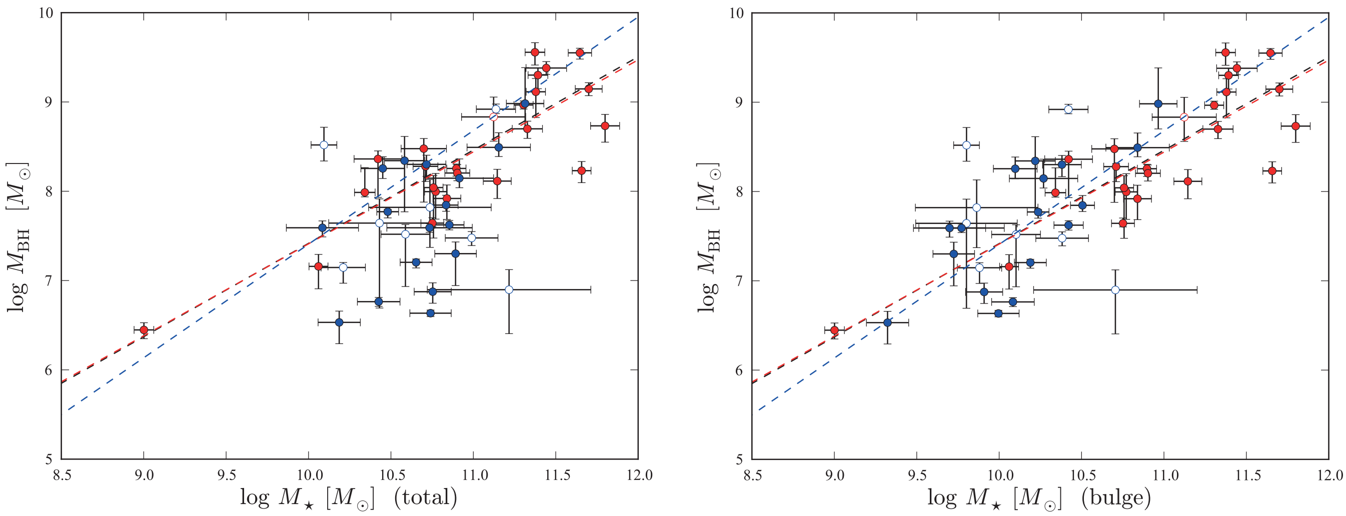

Fig. 2. Left: SMBH mass (red = elliptical galaxies, blue = disk galaxies) versus total galaxy stellar mass. Right: SMBH mass versus bulge stellar mass. (Data and sources in Table A.1.) The diagonal dashed lines are the best fits to the $M_{\rm BH}$-$M_{\star,\rm bul}$ relation for the whole sample (black), for the elliptical galaxies (red), and for bulges of the disk galaxies (blue). Open symbols are galaxies without precise distances, which are not used in the fits. It is clear that the SMBH masses of S0 and spiral galaxies (blue) correlate better with the *bulge* stellar mass than with total galaxy mass.

r_S = 0.76 versus 0.38; the bulge-mass correlation is not statistically significant.) Fitting NSC mass versus total stellar mass, using the same methodology as for the SMBH fits, gives the following relation:

$$\log M_{\rm NSC} \ = \ 7.65 \pm 0.23 \ + \ (0.90 \pm 0.21) \ \log(M_{\star,\rm tot}/10^{11} M_\odot), \qquad (3)$$

with intrinsic scatter = 0.43 ± 0.10 dex. Note that the slope is formally indistinguishable from unity: i.e., the $M_{\rm NSC}/M_{\star,\rm tot}$ ratio does not appear to depend on $M_{\star,\rm tot}$ itself.

It is important to note that the difference in correlation coefficients actually *underestimates* the true difference between the two relations, because the $M_{\rm NSC}$-$M_{\star,\rm bul}$ correlation was computed assuming that bulgeless spirals still have nominal bulges (using $B/T = 0.001$). In the combined sample of dynamical and spectroscopic NSC masses, we can identify at least three galaxies which have no detectable bulge. In two of these (NGC 1493 and NGC 2139), our 2D decomposition assigned stellar light to a bar in addition to a pure exponential disk; in 1D decompositions (or simple bulge+disk 2D decompositions), light from the bar might be (wrongly, we would argue) interpreted as "bulge" light. For the other galaxy (NGC 300), however, there is no ambiguity: this is an unbarred spiral galaxy with a surface brightness profile consisting of *only* an exponential disk and the NSC [see, e.g., Figure 8 of 47].

The existence of nuclear star clusters in genuinely bulgeless spirals is simply an additional, direct confirmation of our basic conclusion: nuclear star cluster masses scale with the total stellar mass of their host galaxies, *not* with the bulge mass. This means that NSCs and SMBHs do not follow a common host-galaxy correlation.

We have also investigated whether other galaxy parameters might correlate with NSC mass, or even with residuals from the $M_{\rm NSC}$-$M_{\star,\rm tot}$ relation. In particular, we have compared NSC mass with rotation velocity and with total *baryonic* mass (stellar mass plus atomic gas from H I measurements). In both cases, correlations exist, but they are not as strong as the correlation with total stellar mass. No particular correlations with residuals of the $M_{\rm NSC}$-$M_{\star,\rm tot}$ relation are seen.

4. Trends with Hubble Type

Closer inspection of the left-hand panel of Figure 3 suggests that the spectroscopic masses (black diamonds) tend to be offset from the NSC-$M_{\star,\rm tot}$ relation, in the sense that they have larger NSC masses for the same total stellar mass. This could, in principle, be evidence of a systematic overestimation of NSC masses in the spectroscopic sample, but of the four galaxies in common between Walcher et al. [21] and Rossa et al. [11] only one has a (slightly) higher spectroscopic mass, while the other three have spectroscopic masses slightly *lower* than the dynamical masses. There is, however, another difference to consider: the spectroscopic sample tends to have earlier Hubble types.

This brings us to something which Seth et al. [48] pointed out several years ago, using a larger dataset of NSCs and host galaxies, with NSC masses based (mostly) on colors or assumed M/L ratios. They noted that NSCs in late-type spirals tended to have lower relative masses ($M_{\rm NSC}/M_{\star,\rm tot}$) than early-type spirals and ellipticals.[3] Figure 4 makes this explicit by plotting $M_{\rm NSC}/M_{\star,\rm tot}$ versus Hubble type for the galaxies in Seth et al.'s compilation, plus seven galaxies from our updated dynamical-mass sample which were not in their sample. We have also added galaxy stellar-mass estimates for 16 galaxies that did not have masses in Seth et al., using

[3] Rossa et al. [11] pointed out a similar trend in *absolute* NSC mass for their smaller sample of NSCs in early- and late-type spirals.

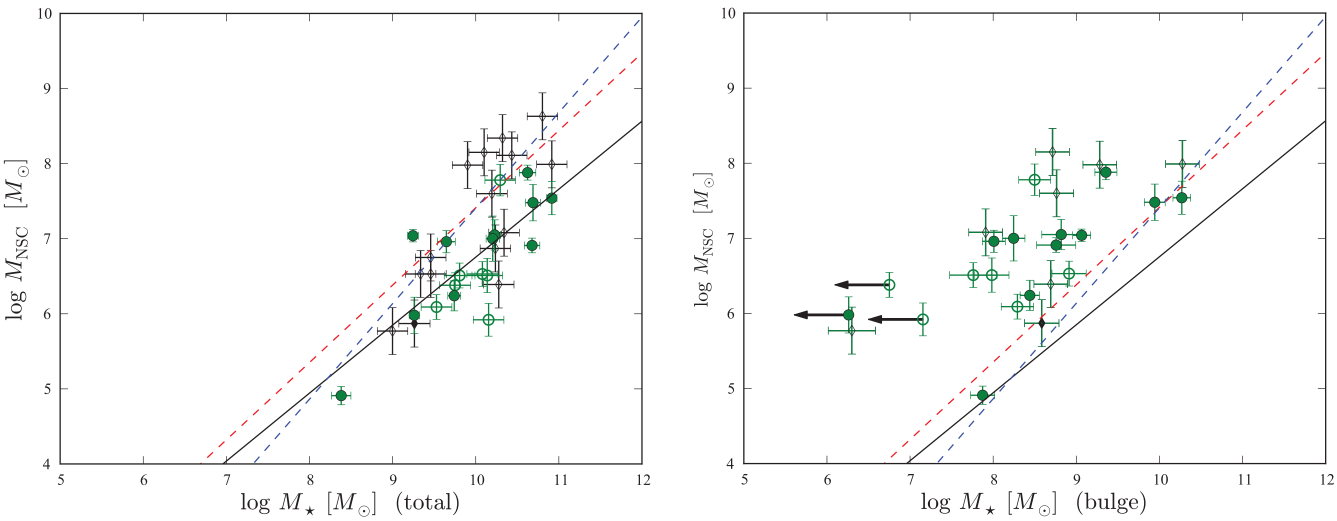

Fig. 3. As for Figure 2, but now plotting NSC mass versus total stellar mass (left) and bulge stellar mass (right). (Data and sources in Table A.2.) Green circles are galaxies with dynamical mass estimates for their NSCs; black diamonds are the spectroscopically estimated masses of Rossa et al. [11] (bulge mass estimates are not complete for these galaxies). Filled symbols indicate galaxies with direct distance measurements (e.g., from Cepheid stars). Arrows show nominal upper limits for three *bulgeless* spirals (assuming $B/T \leq 0.001$). The diagonal black line is a fit of NSC mass to total stellar mass for the dynamical-mass sample (green circles); for comparison, the diagonal dashed red and blue lines are the $M_{\rm BH}$-$M_{\star,\,\rm bul}$ fits for ellipticals (red) and disk galaxies (blue) from Figure 2. The situation is now the reverse of that for SMBHs: NSC masses clearly correlate better with *total* galaxy mass than they do with bulge mass.

total K-band magnitudes from 2MASS and either $B-V$ colors from HyperLeda or measured $g-r$ colors from SDSS images to derive the K-band M/L via Bell et al. [34].

What is curious about Figure 4 is not just that the $M_{\rm NSC}/M_{\star,\,\rm tot}$ ratio depends on Hubble type, but that it actually appears do so in a *bimodal* fashion: Hubble types Sb and earlier have relatively large NSC masses, while Sc and later-type galaxies have significantly smaller relative NSC masses. Plotted on top of the figure are simple fits of a function where the the $M_{\rm NSC}/M_{\star,\,\rm tot}$ ratio can take two constant values, one for Hubble types $T < T_1$ and the other for $T > T_2$, with a simple linear transition between T_1 and T_2. Fits to just the dynamical + spectroscopic masses (red dashed line) and to the entire sample (gray dashed line) are similar, indicating that Sb and earlier Hubble types form one class, with $< M_{\rm NSC}/M_{\star,\,\rm tot} >\sim 0.002$, and Sc and later types form a different group, with $< M_{\rm NSC}/M_{\star,\,\rm tot} >$ almost an order of magnitude smaller (~ 0.0003). The corresponding best-fit values of (T_1,T_2) are (3.51,4.05) for the dynamical + spectroscopic masses and (3.10,5.01) for the complete sample. As a crude check on whether this split is statistically significant, we performed Kolmogorov-Smirnov tests on the values of $M_{\rm NSC}/M_{\star,\,\rm tot}$ for galaxies with $T \leq 3$ and galaxies with $T \geq 5$. The K-S test gives a probability $P_{KS} = 0.0038$ for the two sets of ratios coming from the same parent population if we use only the dynamical + spectroscopic masses, or $P_{KS} = 3.1 \times 10^{-10}$ if we use the entire set of NSC masses.

Do NSCs in late-type spirals differ from those in early-type spirals, S0s, and ellipticals in any sense other than average mass? The available evidence is ambiguous. Böker [7] notes that NSC *sizes* appear to be independent of Hubble type. On the other hand, Rossa et al. [11] compared stellar populations of NSCs in early- and late-type spirals using fits to their spectroscopy and noted that the NSCs in late-type spirals did tend to have younger stellar populations and (slightly) lower metallicities. (They also argued against any observational effects that might produce systematic overestimates of NSC mass in early spirals.) This does at least suggest that different star-formation histories may lie behind the mass differences in NSCs.

We also plot the $M_{\rm BH}/M_{\star,\,\rm bul}$ ratio for SMBH host galaxies (thick gray dotted line in Figure 4, based on Equation 1). What this indicates is that the NSC–host galaxy relationship for Sb and earlier types *is* consistent with the SMBH relation, *if all of the galaxy mass is in the bulge*. Since most of the galaxies used for the original CMO studies [8, 9] were dwarf and giant ellipticals (or S0 galaxies with high B/T ratios), it is easy to see why the "NSC = SMBH" connection could be made. But this is clearly true only for very bulge-dominated systems.

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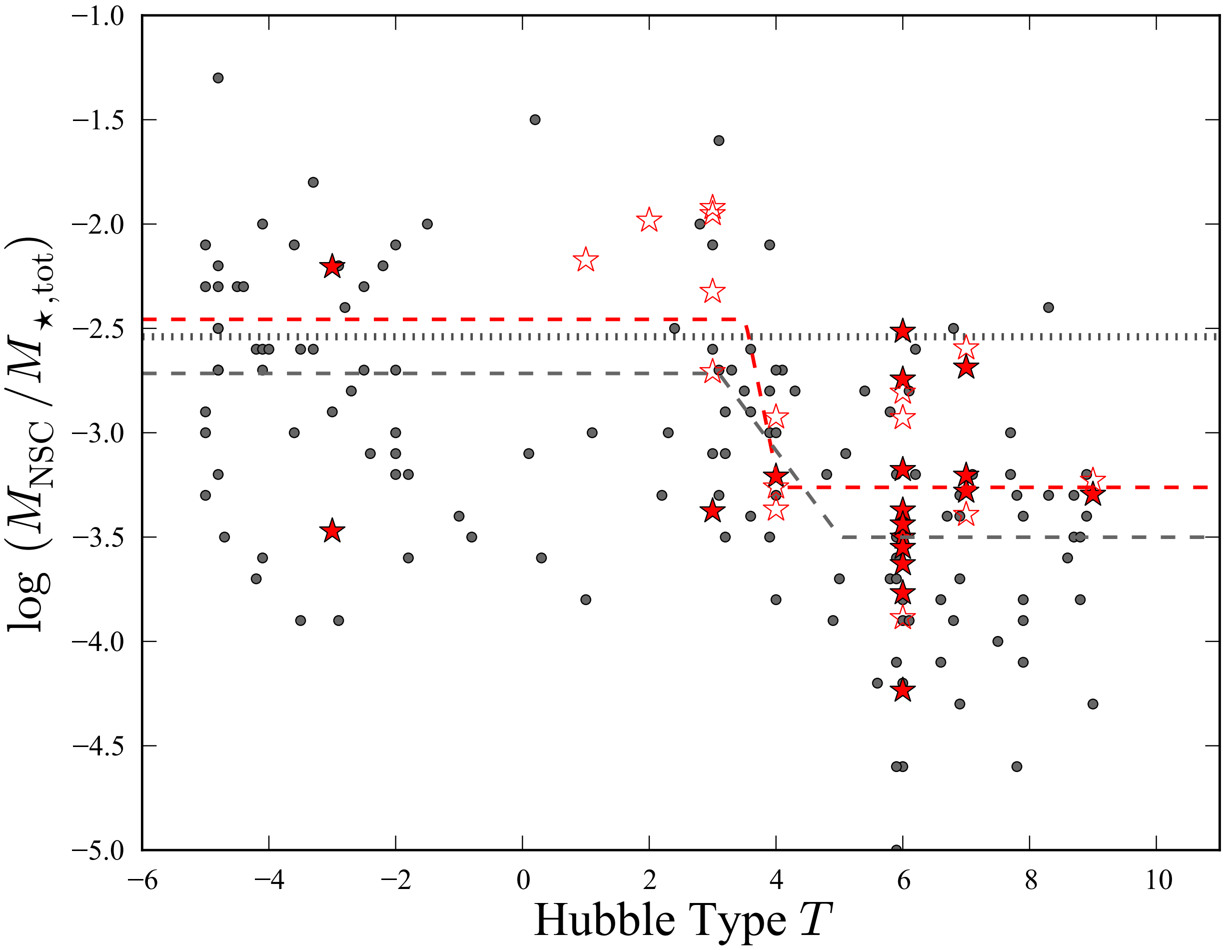

Fig. 4. Relative masses of NSCs versus Hubble type of host galaxy, based on the compilation of Seth et al. [48]. Filled gray circles are NSC masses estimated from broadband colors or assumed M/L ratios by Seth et al. [48]; red stars indicate NSC masses from spectroscopic (hollow) or dynamical (filled) measurements (see Table A.2 for references). Also shown are simple fits to the dynamical+spectroscopic masses (dashed red line) and to the entire sample (dashed gray line), along with the mean mass ratio of SMBHs relative to their host *bulges* (dotted gray line).

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Appendix A: Data Tables

In Tables A.1 and A.2, we list the basic data parameters for SMBH and NSC hosts. References for the NSC masses are in the captions for Table A.2. For the SMBH masses, the numbers in column 5 of Table A.1 translate into the following references: 1 = Gillessen et al. [49]; 2 = Bender et al. [50]; 3 = Verolme et al. [51]; 4 = Krajnović et al. [52]; 5 = Gebhardt et al. [53]; 6 = Bower et al. [54]; 7 = Lodato and Bertin [55]; 8 = Atkinson et al. [56]; 9 = Rusli et al. [57]; 10 = Nowak et al. [58]; 11 = Houghton et al. [59]; 12 = Sarzi et al. [60]; 13 = Devereux et al. [61]; 14 = Davies et al. [62]; 15 = Barth et al. [63]; 16 = Nowak et al. [39]; 17 = Kondratko et al. [64]; 18 = Gültekin et al. [65]; 19 = de Francesco et al. [66]; 20 = Hicks and Malkan [67]; 21 = Miyoshi et al. [68]; 22 = Ferrarese et al. [69]; 23 = Cretton and van den Bosch [70]; 24 = Walsh et al. [71]; 25 = Macchetto et al. [72]; 26 = Nowak et al. [73]; 27 = Shen and Gebhardt [74]; 28 = de Francesco et al. [75]; 29 = Neumayer et al. [76]; 30 = Capetti et al. [77]; 31 = Ferrarese and Ford [78]; 32 = van der Marel and van den Bosch [79]; 33 = Cappellari et al. [80]; 34 = Dalla Bontà et al. [81].

Table A.1. Galaxies with Well-Determined SMBH Masses

Name	T	D (Mpc)	$M_{\rm BH}$ (+, −) ($\log_{10}$ $M_{\odot}$)	Source	Total $M_{\star}$(err) ($\log_{10}$ $M_{\odot}$)	Bulge $M_{\star}$(err) ($\log_{10}$ $M_{\odot}$)
Milky Way	4	0.01	6.63 (+0.03, −0.04)	1	10.74 (0.09)	10.00 (0.13)
M31	3	0.77	8.15 (+0.22, −0.10)	2	10.92 (0.06)	10.27 (0.21)
M32	-5	0.79	6.45 (+0.08, −0.10)	3	9.00 (0.06)	9.00 (0.06)
NGC524	-1	23.3	8.92 (+0.04, −0.02)	4	11.14 (0.09)	10.42 (0.12)
NGC821	-5	23.4	7.92 (+0.15, −0.23)	5	10.84 (0.08)	10.84 (0.08)
NGC1023	-1	11.1	7.62 (+0.04, −0.04)	6	10.85 (0.08)	10.42 (0.09)
NGC1068	3	14.3	6.90 (+0.14, −0.21)	7	11.22 (0.49)	10.71 (0.50)
NGC1300	4	18.9	7.82 (+0.29, −0.29)	8	10.74 (0.37)	9.86 (0.37)
NGC1316	-5	21.3	8.23 (+0.10, −0.13)	9	11.66 (0.06)	11.66 (0.06)
NGC1399	-5	21.1	9.11 (+0.15, −0.29)	10	11.38 (0.06)	11.38 (0.06)
NGC2549	-2	12.3	7.15 (+0.02, −0.16)	4	10.21 (0.12)	9.88 (0.13)
NGC2748	4	23.1	7.64 (+0.25, −0.74)	8	10.43 (0.30)	9.80 (0.31)
NGC2787	-1	7.28	7.59 (+0.04, −0.06)	11	10.08 (0.15)	9.70 (0.22)
NGC3031	1	3.63	7.85 (+0.11, −0.07)	12	10.83 (0.06)	10.51 (0.07)
NGC3227	1	22.9	7.30 (+0.13, −0.35)	13	10.89 (0.11)	9.72 (0.13)
NGC3245	-1	20.3	8.30 (+0.10, −0.12)	14	10.72 (0.09)	10.38 (0.12)
NGC3368	2	10.5	6.88 (+0.09, −0.12)	15	10.75 (0.09)	9.91 (0.11)
NGC3377	-5	10.9	7.99 (+0.28, −0.05)	5	10.34 (0.06)	10.34 (0.06)
NGC3379	-5	10.3	8.00 (+0.20, −0.31)	5	10.77 (0.07)	10.77 (0.07)
NGC3384	-1	11.3	7.20 (+0.03, −0.05)	5	10.65 (0.08)	10.19 (0.10)
NGC3393	1	48.3	7.48 (+0.03, −0.03)	16	10.99 (0.15)	10.38 (0.16)
NGC3489	-1	11.7	6.76 (+0.04, −0.04)	15	10.43 (0.08)	10.08 (0.13)
NGC3585	-3	19.5	8.49 (+0.16, −0.09)	17	11.15 (0.09)	10.84 (0.19)
NGC3607	-5	22.2	8.11 (+0.13, −0.19)	17	11.15 (0.08)	11.15 (0.08)
NGC3608	-5	22.3	8.28 (+0.02, −0.16)	5	10.71 (0.08)	10.71 (0.08)
NGC3998	-2	13.7	8.34 (+0.27, −0.56)	18	10.58 (0.09)	10.22 (0.12)
NGC4026	-3	13.2	8.26 (+0.12, −0.09)	17	10.45 (0.12)	10.10 (0.13)
NGC4151	2	14.5	7.52 (+0.10, −0.56)	19	10.59 (0.13)	10.10 (0.15)
NGC4258	4	7.18	7.59 (+0.04, −0.04)	20	10.73 (0.08)	9.77 (0.26)
NGC4261	-5	30.8	8.70 (+0.08, −0.10)	21	11.33 (0.09)	11.33 (0.09)
NGC4291	-5	25.5	8.48 (+0.10, −0.57)	5	10.70 (0.14)	10.70 (0.14)
NGC4342	-1	16.7	8.52 (+0.20, −0.18)	22	10.09 (0.07)	9.80 (0.08)
NGC4374	-5	18.5	8.97 (+0.04, −0.04)	23	11.30 (0.06)	11.30 (0.06)
NGC4473	-5	15.3	8.04 (+0.13, −0.56)	5	10.76 (0.06)	10.76 (0.06)
NGC4486	-5	16.7	9.56 (+0.11, −0.14)	24	11.37 (0.06)	11.37 (0.06)
NGC4486A	-5	18.4	7.16 (+0.13, −0.25)	25	10.06 (0.06)	10.06 (0.06)
NGC4564	-3	15.9	7.77 (+0.02, −0.07)	5	10.48 (0.06)	10.24 (0.07)
NGC4649	-5	16.4	9.30 (+0.08, −0.15)	26	11.39 (0.06)	11.39 (0.06)
NGC4697	-5	12.5	8.26 (+0.05, −0.09)	5	10.90 (0.06)	10.90 (0.06)
NGC5077	-5	37.5	8.83 (+0.21, −0.23)	27	11.12 (0.19)	11.12 (0.19)
NGC5128	-5	3.42	7.64 (+0.06, −0.03)	28	10.75 (0.07)	10.75 (0.07)
NGC5252	-2	92.9	8.98 (+0.40, −0.27)	29	11.31 (0.09)	10.97 (0.11)
NGC5576	-5	24.8	8.20 (+0.09, −0.08)	17	10.90 (0.08)	10.90 (0.08)
NGC5845	-5	25.2	8.36 (+0.07, −0.41)	5	10.42 (0.15)	10.42 (0.15)
NGC6251	-5	95.9	8.73 (+0.12, −0.18)	30	11.80 (0.09)	11.80 (0.09)
NGC7052	-5	67.9	8.58 (+0.23, −0.22)	31	11.49 (0.12)	11.49 (0.12)
NGC7457	-1	12.9	6.53 (+0.12, −0.23)	5	10.19 (0.10)	9.32 (0.13)
IC1459	-5	28.4	9.38 (+0.05, −0.04)	32	11.44 (0.12)	11.44 (0.12)
IC4296	-5	53.2	9.15 (+0.06, −0.07)	33	11.70 (0.08)	11.70 (0.08)
A1836-BCG	-5	155.6	9.55 (+0.05, −0.06)	33	11.65 (0.07)	11.65 (0.07)

(1) Galaxy name. (2) Hubble type T from RC3. (3) Adopted distance in Mpc. (4) Logarithm of SMBH mass and uncertainties; masses have been rescaled using the distances column 2, if necessary. Uncertainties are 1-σ values. (5) Source of SMBH measurement. (6) Logarithm of total galaxy stellar mass and uncertainty (see text for details). (7) Logarithm of bulge stellar mass and uncertainty, based on 2D decompositions in Erwin & Gadotti (2012b, in prep).

Table A.2. Galaxies with Well-Determined NSC Masses

Name	T	D (Mpc)	$M_{\rm NSC}$ (err) ($\log_{10} M_\odot$)	Type	Source	Total $M_\star$(err) ($\log_{10} M_\odot$)	Bulge $M_\star$(err) ($\log_{10} M_\odot$)
Milky Way	4	0.01	7.48 (0.09)	D	1	10.74 (0.09)	10.00 (0.13)
M31	3	0.77	7.54 (0.06)	D	2	10.92 (0.06)	10.27 (0.11)
M33	6	0.81	6.24 (0.08)	D	3	9.74 (0.08)	8.44 (0.12)
IC342	6	3.37	7.05 (0.07)	D	4	10.23 (0.07)	8.82 (0.23)
NGC300	7	2.02	5.98 (0.06)	D	5	9.26 (0.06)	< 6.26
NGC404	-3	3.18	7.04 (0.06)	D	6	9.24 (0.06)	9.06 (0.11)
NGC428	9	15.5	6.51 (0.18)	D	5	9.81 (0.18)	7.76 (0.29)
NGC1042	6	17.5	6.51 (0.18)	D	5	10.14 (0.18)	7.98 (0.21)
NGC1493	6	11.0	6.38 (0.19)	D	5	9.75 (0.19)	< 6.75
NGC1705	-3	5.11	4.91 (0.12)	D	7	8.38 (0.12)	7.87 (0.15)
NGC2139	6	22.9	5.92 (0.18)	D	5	10.15 (0.18)	< 7.15
NGC3423	6	14.4	6.53 (0.19)	D	5	10.08 (0.19)	8.91 (0.21)
NGC3621	7	6.64	7.00 (0.08)	D	8	10.20 (0.08)	8.25 (0.14)
NGC5457	6	7.05	6.91 (0.09)	D	9	10.68 (0.09)	8.76 (0.24)
NGC6946	6	5.89	7.88 (0.10)	D	9	10.62 (0.10)	9.36 (0.13)
NGC7418	6	17.8	7.78 (0.18)	D	5	10.29 (0.18)	8.50 (0.19)
NGC7424	6	10.5	6.09 (0.18)	D	5	9.53 (0.18)	8.29 (0.19)
NGC7793	7	3.91	6.96 (0.11)	D	5	9.65 (0.11)	8.01 (0.14)
NGC1325	4	19.6	7.08 (0.18)	S	10	10.34 (0.18)	7.91 (0.20)
NGC1385	6	18.1	6.39 (0.18)	S	10	10.28 (0.18)	8.69 (0.20)
NGC2552	9	9.68	5.77 (0.18)	S	10	9.00 (0.18)	6.30 (0.28)
NGC3177	3	19.6	8.15 (0.18)	S	10	10.10 (0.18)	8.71 (0.20)
NGC3277	2	21.4	8.34 (0.18)	S	10	10.32 (0.18)	…
NGC3455	3	16.4	6.75 (0.18)	S	10	9.46 (0.18)	…
NGC4030	4	20.5	7.99 (0.18)	S	10	10.92 (0.18)	10.28 (0.20)
NGC4411B	6	18.6	6.53 (0.19)	S	10	9.46 (0.19)	…
NGC4701	6	10.8	6.53 (0.18)	S	10	9.34 (0.18)	…
NGC4775	7	21.9	7.60 (0.19)	S	10	10.19 (0.19)	8.76 (0.20)
NGC5377	1	28.4	8.63 (0.18)	S	10	10.80 (0.18)	…
NGC5585	7	8.71	5.87 (0.19)	S	10	9.26 (0.19)	8.58 (0.21)
NGC5806	3	20.0	8.11 (0.18)	S	10	10.43 (0.18)	…
NGC7421	4	23.1	6.87 (0.18)	S	10	10.24 (0.18)	…
NGC7690	3	17.7	7.98 (0.18)	S	10	9.90 (0.18)	9.28 (0.20)

(1) Galaxy name. (2) Hubble type T from RC3. (3) Adopted distance in Mpc. (4) Logarithm of NSC mass and uncertainty; masses have been rescaled using the distances column 2, if necessary. Errors are 1-σ values. (5) Type of NSC mass measurement: "D" = dynamical, "S" = spectroscopic. (6) Source of NSC measurement: 1 = Launhardt et al. [31]; 2 = Kormendy and Bender [25]; 3 = Matthews et al. [26] + Gebhardt et al. [27]; 4 = Böker et al. [24]; 5 = Walcher et al. [21]; 6 = Seth et al. [29]; 7 = Ho and Filippenko [23]; 8 = Barth et al. [28]; 9 = Kormendy et al. [30]; 10 = Rossa et al. [11]. (7) Logarithm of total galaxy stellar mass and uncertainty (see text for details). (8) Logarithm of bulge stellar mass and uncertainty (or upper limit for bulgeless galaxies), based on decompositions in Erwin & Gadotti (2012a, in prep); galaxies currently missing proper decompositions are indicated by "…".